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U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

SMART Mobility Multi-Modal Pillar

2017 U.S. DOE Vehicle Technologies Office Annual Merit Review Meeting

DIANE DAVIDSON, OAK RIDGE NATIONAL LABORATORY

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June 7, 2017

Argonne NATIONAL LABORATORY

INL Idaho National Laboratory

BERKELEY LAB

OAK RIDGE National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

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SMART Mobility Multi-Modal Pillar Team

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Overview of the SMART Mobility Multi-Modal Pillar

Pillar purpose is to assess the impacts of achieving energy-efficient movement of passengers and freight within and between urban areas.

Timeline

- Project start: Oct. 2016
- Project end: Sept. 2019
- Percent Complete: 17%

Budget

- Total DOE funding: $4.5M
- FY 2017: $1.5M

Barriers

- Lack of knowledge of energy efficiencies from technology options and traveler/shipper choices
- Limited understanding of impacts of carsharing and transportation network companies (TNCs) on energy consumption and their relationship with transit
- Gaps in freight mode share data advanced technology modal shifts

Relevance of the Multi-Model Pillar

Advanced technologies, new business models and data, will transform the flow of people and goods, introducing opportunities for potentially profound changes on energy

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Intra-city passenger travel options (shared vehicles, carsharing and TNC's), to be evaluated/integrated with transit choices for improved energy profiles

Inter-city freight techniques and shifts in delivery modes may have significant national-level impact on energy use, infrastructure and operations strategies

New **intra-city freight delivery modes** will impact infrastructure and energy demand

Models, analysis and data will provide a better **system-level understanding** of technology-related energy reduction impacts and consumer/fleet choices at the city, regional and national levels by short, medium and long term scales

Project Objectives

1. **Estimate regional energy impacts of passenger transit policies using new and enhanced models**
2. **Establish characterization/optimization of intra-city freight delivery modes**
3. **Estimate national and regional energy impacts of inter-city freight efficiency improvements and possible mode shifts**

Key objectives addressed this period:

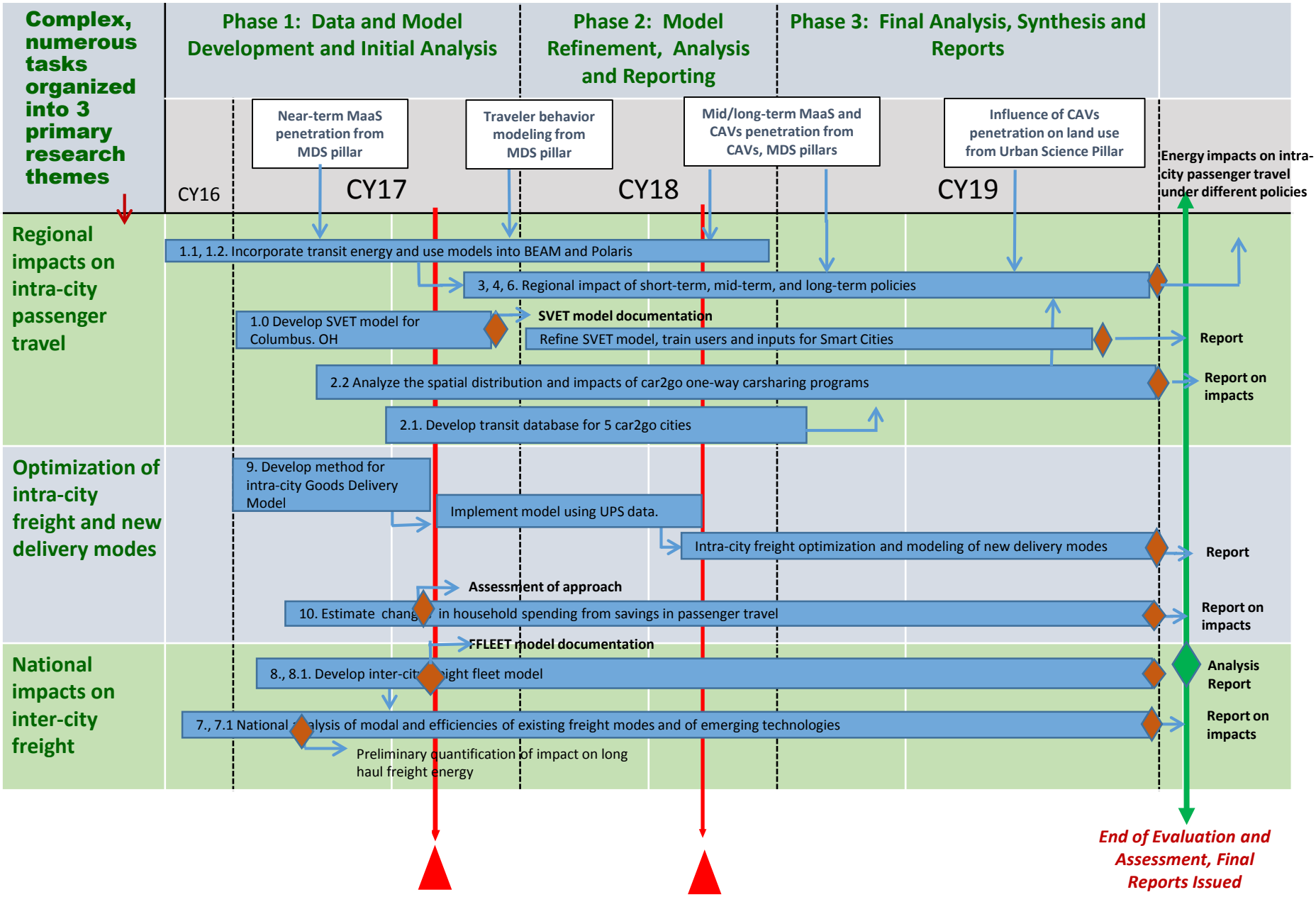
Data Collection

- Collected data on **carsharing** in 5 cities on its relationships with conventional transit
- Collected data on **freight modes and models** which can be used for inter-city and intra-city characterization

Model Development

Initiated/revised models to quantify the energy savings potential from SMART technologies for passenger and freight vehicles/fleets

Multi-Modal Pillar Roadmap



Approach

Intra-city passenger travel

1. Enhance **model capabilities to assess changes in passenger travel** in SF Bay, Chicago, Columbus
   - Estimate baseline and future energy use under different scenarios and timescales
2. Develop fleet model to **manage advanced technology / alternative fuel vehicles** in city fleets
3. Study **shifts in household spending** induced by increased TNC/carsharing and reduced private vehicle ownership
4. Evaluate the extent to which TNCs are competing with or supporting conventional transit
5. Integrated with other SMART Mobility Pillar projects:
   - From MDS Pillar - MaaS penetration level and traveler behavior
   - From CAVs and Urban Science Pillar – CAV penetration level and influence on land use
   - Smart City Columbus collaboration

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Approach

Intra-city (urban) freight delivery

- Establish baseline for freight delivery modes and technology and **identify and characterize new vehicle choices and modes for freight delivery** (drones, electric vehicles, contracted delivery, etc.)
- Develop **tour-based model to enhance realism** in modeling to capture the impact of innovative and novel goods movements and service deliveries.
  - Use energy efficiency data from the freight fleet models to enhance the tour model.

Image from iStock Photo

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Image courtesy of UPS

Approach

Inter-city freight transport

- Create fleet level model to estimate energy/GHG impacts from **technology and modal shifts**.
  - Incorporate results from CAVs pillar analysis to characterize benefits from key Smart Mobility technologies
- Evaluate **national energy use** impacts by analyzing **multiple scenarios** which account for **energy efficiency, travel demand, VMT changes and modal distributions**
- Work with shipping fleets to better understand changes to **alternative freight transport modes** and the influence of EEMS on their decisions to use them

Federal Motor Carrier Safety Administration Photo disk

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FY17 Milestones by Quarter

Summary Tasks		Milestones
Q2	High-level energy/GHG impact scenario analysis of different technologies (e.g. truck platooning, vehicle automation, improved logistics) on national scale multi-modal, long-haul freight. (ANL)	Preliminary impact quantification of long haul freight energy implications. 
Q3	Tour-based modeling for evaluation of city level freight investments and energy efficiencies by capturing the impact and growing complexity of novel goods movements and service deliveries. (ORNL) (INL)	Methodology and data needs for intra-city freight modeling most applicable to local shared service delivery.
Q3	Collect public transit infrastructure, route GTFS, and ridership data from regional transit agencies operating in five cities. (INL) (LBNL)	Develop a database of transit energy use for five cities.
Q4	Demonstrate a web based version of Smart Vehicle Energy Technology (SVET) passenger fleet model, using Columbus OH as prototype. (ORNL) (NREL)	Develop a Energy Calculator to assist with smart city fleet procurement and operations, as well as producing inventories and "what if" scenarios.
Q4	Enhance the BEAM traffic assignment model to estimate the impact of changes in public transit and new transportation services on energy consumption in the San Francisco Bay region. (LBNL)	Develop a transit vehicle energy module for use in the BEAM model.

FY18 Milestones by Quarter

	Summary Tasks	Milestones
Q3	Estimate effect of short-term changes in system operations, signal priority for transit, RTIS driven behavioral change, vehicle electrification, TNC support of public transit, TNC replacement of low ridership transit lines.	Estimated effects of short-term changes to distribution of travel by mode, and energy consequences, in SF Bay Area.
Q3	Following modeling and analysis of energy consumption of transit vehicles, buses and trains, integrate transit energy models into the bigger framework in preparation for a FY19 case study in Chicago.	Estimation of trends in multimodal passenger travel that affect overall energy use over an entire metro area.
Q4	Literature review of impacts of one-way carsharing and bikesharing systems. Analysis of user survey location data and spatial distribution of modal shift, using data from car2go one-way carsharing programs in five cities.	Analysis of the energy impacts of one-way carsharing programs.
Q4	Refine Freight Analysis Framework data to a regional level for ton and value by mode for the Columbus OH area. Work becomes the foundation for using as inputs to the Freight Fleet Level Energy Estimation Tool and ANL's NEAT Model.	Detailed data and analysis on regional freight movements in the mid-Ohio region for use by Smart City Columbus for decision-making.

Technical Accomplishments and Progress

Intra-city passenger travel

Data

- Obtained AT&T cell phone records for use in developing similar model for Columbus
- Began analysis of data from one-way car sharing program (car2go) in five cities
- Began gathering and analysis of transit data in car sharing cities
- Received and analyzed fleet operations data from Smart City Columbus to feed scenario evaluation using SVET

Intra-city passenger travel

Models

1. Smart Vehicle Efficiency Technology (SVET) **web-based passenger fleet model** development nearly complete
2. Converted existing SF SmartBay model to BEAM, to enable distributed computing for **larger/faster simulations of individual traveler decisions**

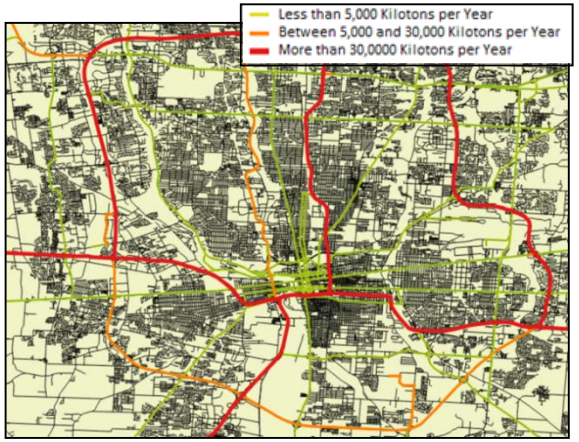
   Incorporated transit vehicle routes & schedules into BEAM
3. Developed **vehicle energy consumption models** using Autonomie for transit buses for multiple powertrain configurations, including hybrids. The models will be used to estimate the energy impact using POLARIS

- BEAM and POLARIS are agent-based models that simulate behavior of individual travelers
- Traveler's route choice is constrained by travel time, duration, and cost constraints, as well as transportation system capacity
- Models can simulate trips that include multiple transport modes (e.g. walk, transit, personal vehicle, etc.)

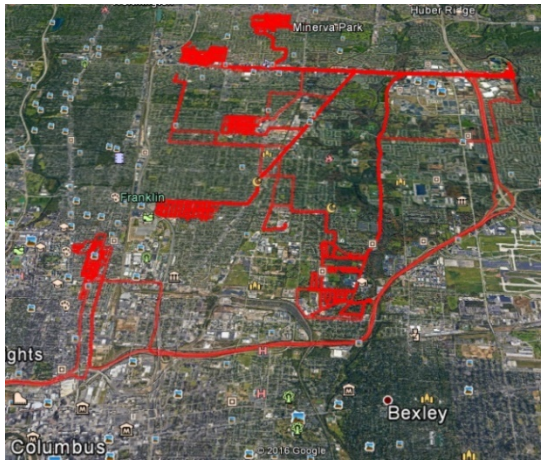
Technical Accomplishments and Progress

Intra-city goods delivery

- Compiled freight movement & volume data within Columbus (MORPC, FAF, UPS) to **characterize intra-city freight energy use**.
  - Data to be used for validation of freight volume, OD movements and energy use assumptions to assess energy saving MM options.
- Literature review on freight Tour Model methods
- Identified new modes and vehicle efficiency improvements and began characterization of energy profiles of these potential vehicles & modes
- Analyzing consumer data on household transportation expenditures



Columbus Freight Volume Data

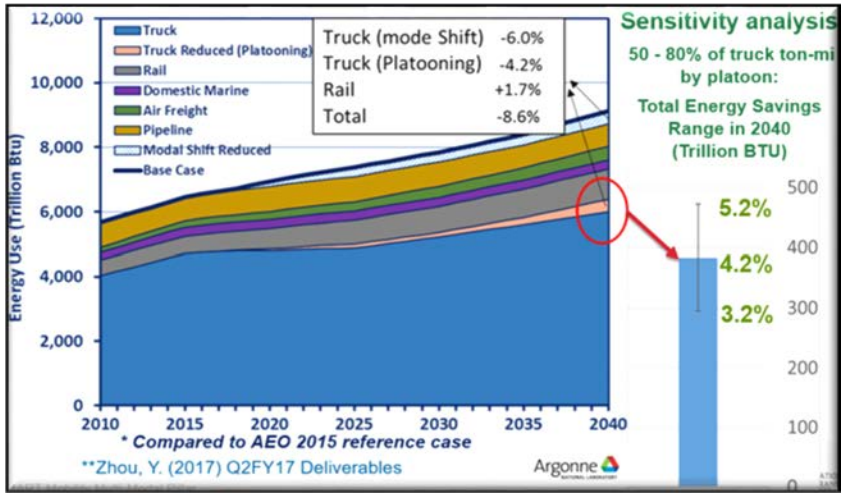


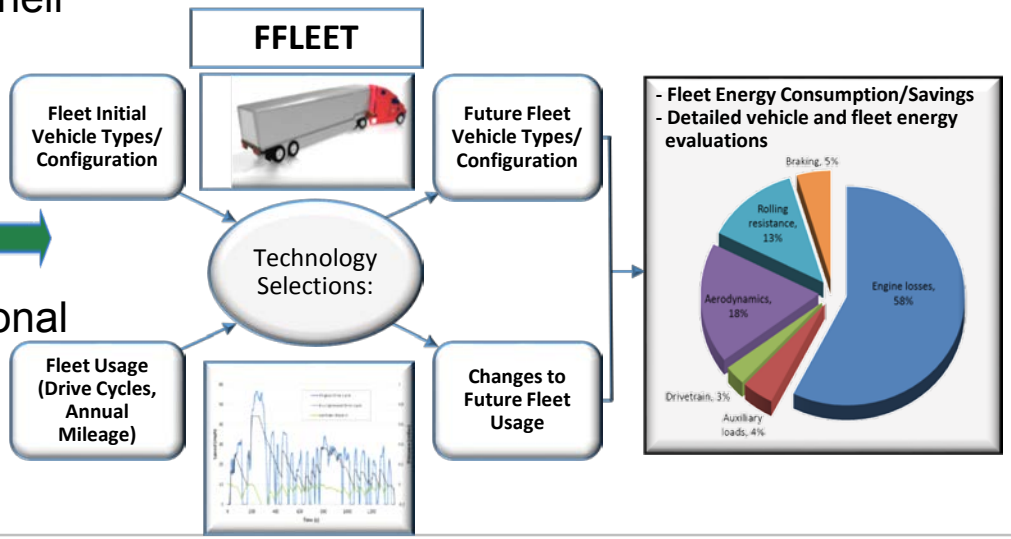
Sample Columbus Package Movement Data

Technical Accomplishments and Progress

Inter-city freight transport

- Preliminary national estimate by NEAT model shows up to **5.2% annual energy reduction due to truck platooning** in 2040
- Analysis models for national-level impacts initially assessed and revised
- UPS to provide data on modal distributions, O-D data and vehicle operations in/out of their Columbus freight hub
- Freight Fleet-Level Energy Efficiency Technology (FFLEET) model nearly complete
- Gathered data for energy profiles and national freight modes





Partners/Collaborators

National Laboratory Partners

- ORNL, ANL, INL, LBNL, NREL
- In coordination with other SMART Mobility pillars: AFI, CAVs, MDS, US
- ARPA-E: TRANSNET projects in 5 cities

University Partners

- UC Berkeley: subcontractor, conduct analysis of TNC programs based on existing relationships with Uber and Lyft
- Morehouse College: Analysis of household expenditures

Industry Partnerships

- AT&T: industry partner, cell phone data for Columbus model development
- Car2go: industry partner, data on one-way carsharing program
- UPS: Operational data for trucks, rail and package delivery cars

Metropolitan Partnerships

- City of Columbus: data on passenger fleet operations and energy use
- Metropolitan transit agencies: data on transit routes, schedules, vehicles

Remaining Challenges and Barriers

Intra-city passenger travel needs

- Improved model data for evaluating energy benefits from modal shifts
- Greater understanding of links between TNC use and conventional transit
- Introductory Columbus data received but need complete vehicle drive cycle and fuel data
- Input data on effectiveness of real-time transit information systems and TNCs in supporting conventional transit

Intra-city (urban) freight delivery needs

- Further characterization of new modes of goods delivery in urban environments.
- Work with delivery providers to understand adoption rates and impacts
- Additional information on the energy profiles for new vehicle options such as drones
- enhance tour-based models to identify finer detail on energy impacts and how to represent shifts in modes.

Inter-city freight transport needs

- More analysis on effect of new transport technologies on modal share
- More accurate energy impacts of Smart Mobility technologies, including partial technology penetration (CAVs pillar to provide further inputs)
- Finalize UPS NDA

Proposed Future Research (FY18/19)

Intra-city passenger travel

- Begin analyzing short-term scenarios by mid-FY18
  - Pricing policies
  - Signal prioritization for transit vehicles (with Urban Science pillar)
  - Greater traveler use of RTIS to support and expand conventional transit
  - Begin mid-/long-term scenarios by mid-FY19
  - Extensive use of TNCs and CAVs to support or compete with conventional transit
  - CAVs influence on future land use patterns (with CAVs and US SMART pillars)

Intra-city (urban) freight delivery

- Identify new methods, such as neighborhood-depots and uber-type delivery, to incorporate into tour-based models
- Work with delivery providers to characterize and optimize freight mode changes
- Provide energy impacts and recommendations on adoption methods

Inter-city freight transport

- Create profiles of energy savings adoptions and demonstrate impacts of adoption rates.
- Create more granular national-level models that demonstrate shifts of consumer demands and freight behaviors

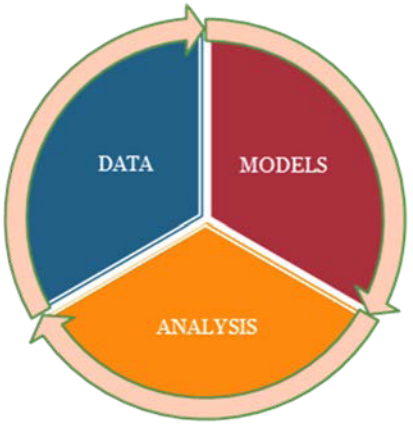
Summary

Relevance

- Possible SMART Mobility technologies will have **profound changes** on the transport of people and goods, but the **uncertainties of energy impacts** need to be addressed.
  - Passenger travel options, such as shared vehicles, carsharing and TNC's, need to be evaluated and integrated with transit choices to improve energy profiles
  - New intra-city freight delivery modes will impact infrastructure and energy demand
  - Inter-city freight optimization techniques and shifts in delivery modes may have significant
- Develop **improved models** of multi-modal passenger travel and freight movement

Approach

- Collect **data** on use of new technologies and modes
- **Model and analyze** scenarios of new travel and freight movement with new technologies and modes
- **Collaboration** and partnerships are key elements



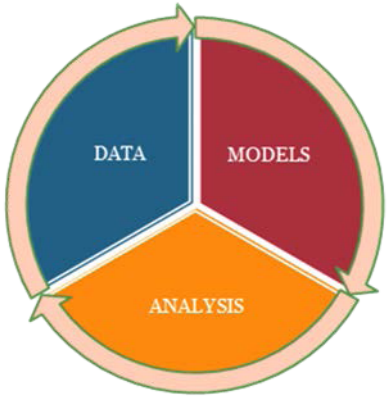
Summary

Progress

- Progress in **intra-city travel modeling and data**
- Initial assessment of inter-city freight impacts of truck platooning

Proposed future research

- **Simulate and analyze** intra-city passenger **travel scenarios with new travel modes**
- **Develop and analyze** scenarios of intra-city freight delivery and inter-city freight movement



Exploring the untapped transportation system-level efficiencies

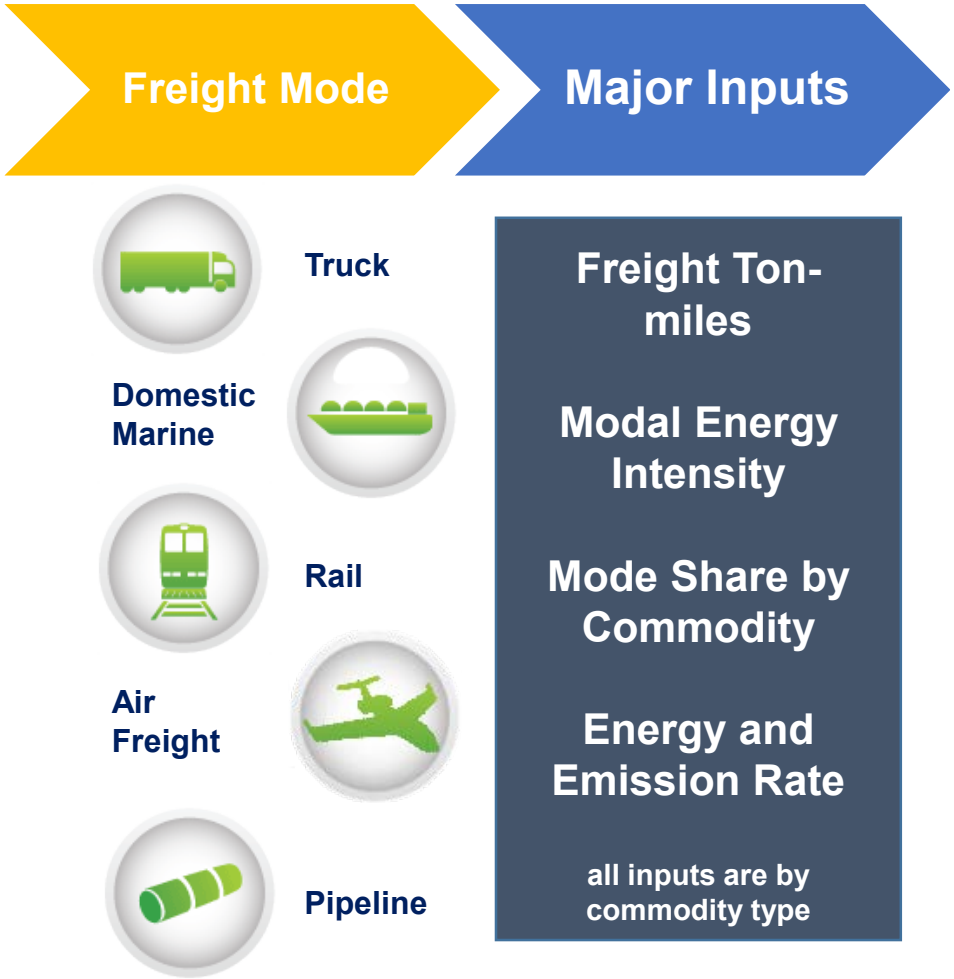
Technical Back-Up Slides

National Scale Energy Analysis

Accomplishments:

- SMART Mobility: Argonne's NEAT model can identify "size of the prize" of **inter-city** freight due to
  - ➢Potential mode shift
  - ➢Improved efficiency (e.g. platooning)
  - ➢Demand changes by commodity
  - ➢Increased alternative fuel use
  - ➢Alternative economic, regulatory, and policy scenarios

- NEAT model is publicly available, annually updated and calibrated to match AEO and FAF projections



NEAT: https://www.anl.gov/energy-systems/project/neat-non-light-duty-energy-and-ghg-emissions-accounting-tool

Regional Benefits of Increased Transit Use (SF Bay Area, BEAM)

Accomplishments:

- Converted existing SmartBay model to BEAM, to enable distributed computing for larger and faster simulations
  - Core capability, movement behavior and mode choice, dispatch scheduling completed
  - Multiple choice models, routing service, and congestion modeling to be completed by end of FY17
- Expanded BEAM to handle transit vehicles
  - Incorporated GTFS data from 28 Bay Area transit agencies
  - Assigned fuel use to vehicle types
  - Obtained Clipper card data on vehicle boardings by time of day and route, to calibrate traveler mode choices in BEAM

Challenges:

- Additional functionality to be added in FY18, based on results in existing literature
  - Travelers replacing transit with TNCs and ridesharing
  - TNCs as an additional mode to/from transit stations
  - Create shadow network to simulate signal prioritization for buses
- More research can provide better inputs to improve modeling
- BEAM is currently assigning travel activity provided by MTC; eventually use cell phone data to generate travel activity within BEAM

Smart Vehicle Energy Technology (SVET) Passenger Fleet Model

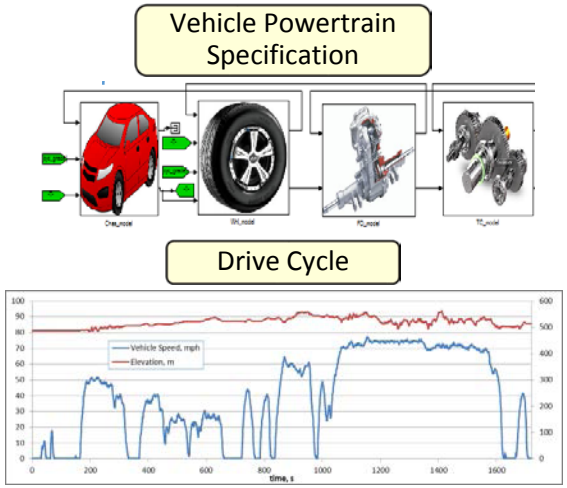
Objective:

- Web-based tool to aid city fleet managers in the evaluation of energy benefits for alternative fuel/energy efficient vehicles
- Accelerate energy efficiencies across passenger fleets, prioritize most effective technologies based on actual fleet use

Approach:

- Full-fleet evaluation, with simplified data entry to shorten the full-fleet profile creation
- Physics-based vehicle model: tractive power and efficiency analysis
- Selected technologies modeled via influence on primary vehicle parameters and modification to drive cycles (CAV technologies)
- To develop the full fleet evaluation, selections of the vehicle specification and usage are automated as much as possible to simplify fleet profile creation
- Several user options to select/identify relevant drive cycles, including GIS based analysis to determine road speed and grade from routes

Vehicle configuration and usage



Automated entries for ease of use:

- Default parameters entered based on selected technologies, but user may modify entries if has more specific data
- Drive cycle impacts (CAV technologies) will be evaluated using sub-models that smooth the original drive cycle
- For passenger car models, a link will allow selection of the particular vehicle option from the fueleconomy.gov website

Usage specification:

In addition to measured or regulatory cycle, automated tools can estimate a drive cycle based on a specified route or travel within specified region, based on GIS analysis

EV/Hybrid sizing options:

- Automated sizing of motor/battery for generic model, or detailed user specification

Vehicle library allows easy selection/ reuse of existing vehicles

- Many default vehicle types, and user can reuse and modify any model previously created

Specification data must be entered for each vehicle type and usage to specify the complete fleet profile

Freight Fleet-Level Energy Estimation Tool (FFLEET)

Objective:

- Develop a web-based model to estimate freight fleet level energy consumption of innovative SMART transportation systems, alternative fuel technologies and freight modal shifts

Approach:

- Full-fleet evaluation, allows energy comparisons between the current fleet and scenarios for future deployment of advanced vehicle technologies

Accomplishments:

- Literature review completed Q1
- Tractive energy/vehicle efficiency model, development mostly complete
- UPS agreed to provide fleet and vehicle operation data from Columbus for validation (NDA being processed) as well as feedback on model

Technologies Available for Evaluation in FFLEET

Vehicle types	Powertrain types	CAV technologies	Other fuel efficiency technologies
Class 7-8 tractor-trailers (day cabs and sleeper cabs)	Conventional internal combustion engine (gas, diesel, or natural gas)	Traffic signal eco-approach and departure	Aerodynamic drag reduction devices (advanced cabin fairings, trailer skirts, boat tails, trailer gap reduction, under body drag reduction, wheel covers)
Box/straight trucks (refrigerated or not)	High pressure direct injection (HPDI) engine (dual fuel natural gas-diesel)	Connected Eco-Driving	Low rolling resistance tires
Delivery/step vans	HEVs (series and parallel configurations)	Advanced cruise control technologies (ACC and CACC)	Speed limiters
Car carriers	PHEVs	Grade/traffic-based powertrain control and optimization (e.g. Intelligent Powertrain Management)	Auxiliary Power Units (APUs)
Flatbed trucks	BEVs	Platooning	Advanced transmissions
Freight trains	Other all-electric vehicles, including catenary- or rail-powered		Vehicle Lightweighting options (carbon fiber body panels, low mass glider, compacted graphite iron (CGI) block)